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TITLE: Method and Apparatus For Electro-Optical Disk Memory

INVENTORS & RESIDENCES:

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(1) TITLE

Method and Apparatus For Electro-Optical Disk Memory

(2) CROSS-REFERENCE TO RELATED APPLICATIONS

Not applicable.

(3) STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

(4) REFERENCE TO AN APPENDIX

Not applicable.

(5) BACKGROUND

TECHNICAL FIELD

[0001] This disclosure relates generally to disk memories.

DESCRIPTION OF RELATED ART

[0002] In U.S. Patent No. 6,556,470, issued on Apr. 29, 2003, and assigned to the common assignee herein, Kent Vincent, Xiao-an Zhang, and R. Stanley Williams, describe FIELD ADDRESSABLE REWRITABLE MEDIA, incorporated herein by reference in its entirety, including the Appendix thereof (which is selected text of allowed U.S. Pat. Appl. Ser. No. 09/844862, filed 04/27/2001 by Zhang et al.), hereinafter referred to simply as the "Vincent '470 patent." In summary, an electrochromic molecular colorant and a plurality of uses as an erasably writeable medium are described. Substrates are adapted for receiving a coating of

the colorant. Electrical fringe fields or through-fields are used to transform targeted pixel molecules between a first optical state and second optical state, providing information content having resolution and viewability at least equal to hard copy document print.

[0003] One problem associated with known manner magnetic, magneto-optic, and compact disk/digital video disk (CD/DVD) rewritable optical memories is the relatively slow speed associated with writing data. For example, with magnetic storage, writing speed is limited by the inductive impedance of the magnetic write head. As another example of a cause of relatively slow write times, optical storage media use phase-change recording layers where write time is related to thermally crystallizing the media for each bit. Such prior art systems typically achieve only a microsecond-per-bit write time at best. Data density is similarly limited, including limitations inherent in miniaturization of the magnetic particles used for data bit storage. Moreover, magnetic field spread requires accommodative track spacing which lowers total storage capacity.

[0004] CD and DVD memories are generally limited in storage capacity and performance by the achievable field of view of the read-write laser head.

[0005] There is a need for improvements to electro-optical disk

memories.

(6) BRIEF SUMMARY

[0006] The basic aspects of the invention generally provide for an electro-optical disk memory having a rewritable layer employing molecular-level read-write storage mechanisms.

[0007] The foregoing summary is not intended to be inclusive of all aspects, objects, advantages and features of the present invention nor should any limitation on the scope of the invention be implied therefrom. This Brief Summary is provided in accordance with the mandate of 37 C.F.R. 1.73 and M.P.E.P. 608.01(d) merely to apprise the public, and more especially those interested in the particular art to which the invention relates, of the nature of the invention in order to be of assistance in aiding ready understanding of the patent in future searches.

(7) BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIGURE 1 is a schematic, perspective view in accordance with a first exemplary embodiment of the present invention, including enlarged detail sections in partially exploded views.

[0009] FIGURE 2 is a schematic elevation view demonstrating a read-write process in accordance with the exemplary embodiment as shown in FIGURE 1.

[0010] FIGURE 3 is a block diagram of an exemplary system for employing the exemplary embodiments of the present invention

as shown in FIGURES 1 and 2.

[0011] Like reference designations represent like features throughout the drawings. The drawings in this specification should be understood as not being drawn to scale unless specifically annotated as such.

(8) DETAILED DESCRIPTION

[0012] **FIGURE 1** is a schematic, perspective view of a data storage memory 101 in accordance with a first exemplary embodiment of the present invention, including enlarged detail sections in partial exploded views. The storage memory 101 is a rotating disk 103 type rewritable memory device. The disk 103 itself also acts as a recording medium substrate, wherein the recording medium thereon is a molecular colorant; for example, see the Vincent '470 patent. The disk 103 may be fabricated in a known manner using metals, glass, ceramic, plastic, or other materials as common to the state of the art. As described in detail hereinafter, the storage memory 101 has digital data erasably written on the recording medium by using localized electrical fields. The disk 103 substrate may be electrically grounded; illustrated by the arrow labeled "GND." If a non-conductive material is used to fabricated the disk, a grounded, metalized bottom surface may be employed. The grounded disk 103 provides a grounded backplane electrode of the storage

memory 101. Alternatively, given an appropriate fringe field write head as described in the Vincent '470 patent with respect to FIGURE 3AA and as shown in FIGURE 2 described hereinafter, grounding of the disk 103 may become unnecessary.

[0013] On a recording, or "read-write," surface 105 of the disk 103 is a data storage recording medium 107. The recording medium 107 is an electrical-field controlled, switchable, molecular colorant, coated or otherwise affixed in a known manner onto the read-write surface 105. The Vincent '470 patent incorporated herein by reference, and particularly the Appendix thereto, describes the details of the types of molecules 109 used in forming the recording medium 107. For the main part, the colorant forms a recording medium as a layer on a surface of the disk which is a molecular-level operating system including electrochromic, switchable molecules, each of said molecules being selectively switchable between at least two optically distinguishable states. A small segment 107s of the recording medium 107 is shown exploded in view, in a partially transparent illustrative representation of a molecular structure 111 employed in accordance with the present invention. As illustrated, the recording medium 107 is preferably a construction that comprises substantially uniform, planar strata, illustrated herein as three stratum 113, 115, 117. In practice, the number of strata will be

dependent upon the specific molecules 109 employed and the thickness of the recording medium 107. The recording layer is preferably a molecularly self-assembling, interconnected stratum creating a uniform, precisely spaced, conjugated, molecular lattice structure 111. Recognizing that each molecule 109 is effectively an individual molecular switch, it can be recognized that even a known manner thin film deposition onto the recording surface of the disk 103 will form a lattice of the molecular colorant recording medium 107 that includes several hundreds or thousands of stratum, depending on the thickness.

[0014] Each molecule 109 is capable of a band gap transforming conformation change under the influence of an electric field. The band gap transformation occurs via molecular level mechanisms such as (1) molecular conformation change or an isomerization, (2) a change of extended conjugation via chemical bonding change, or (3) molecular folding or stretching; see Vincent '470, particularly the Appendix. In the preferred embodiments of the present invention, each molecule 109 has a one or more aromatic rings having electrical dipoles and can rotate out of the plane of the molecule with an appropriately applied electric field wherein electron conjugation along the molecule is altered, also sometimes referred in the art to as broken, interrupted or destroyed. In this manner each molecule effectively has a

construction that can be considered in electromechanical terms as having a construction in the nature of:

rotor 109r - - connector - - stator 109s,

wherein " - - connector - -" represents an atomic level interconnect. Thus, the lattice structure 111 in effect forms a recording layer 111 which is a matrix of individual molecular-level switches.

[0015] In general, each switch has at least two stable optical states - that is, each molecule 109 is at least bistable and at least bichromal. In one exemplary embodiment, the molecule is absorptive of light when fully planar and transparent to light when conjugation is broken. Thus, provided with a suitably adapted write-erase head of a data recording device 121 and a light emitter-detector device, and using these molecules 109 to form an electro-optical switchable colorant layer as a recording medium 107 on a rotatable disk 103, a system is created for forming a data storage medium, or "disk memory device," 101.

[0016] A variety of write-erase heads can be implemented for use in the system. The Vincent '470 patent and Vincent et al. in U.S. Pat. Appln. Ser. No. 10/981,131 (assigned to the common assignee herein and incorporated herein by reference), describe

a variety of such writing instruments.

[0017] **FIGURE 2** is a schematic elevation view demonstrating one exemplary write-erase head, or a "recording device," 121 and an exemplary write process in accordance with the exemplary embodiment as shown in FIGURE 1. Optical states of individual molecules, or supersets of many latticed molecules forming a predetermined volume of the recording medium 107 - - which may be considered by some practiced in the art as a single molecule when self-assembling mechanisms are employed for fabricating the molecular matrix - - can be used to define one data bit. Data bits, are reversibly recorded, or "written," by a localized electric fringe field, selectively generated by the recording device 121, that passes through the recording medium 107. The data recording device 121 includes an electrical stylus 123. In writing data, the stylus 123 is brought into contact or near-contact relationship with the recording medium 107. An implementation-optimized, small aperture electric field - - represented by the phantom lines 200 emitted by the center electrode 201 of the stylus 123 tip 223 and returning along the two side electrodes 203, 205 - - is applied selectively to the recording medium 107 to write data bits. In other words, the bit density of the recording medium 107 is determined by the line width of the electric field 200. Therefore, the main limitation on

bit density will be with the scalable dimension of the electrodes 201, 203, 205 of the stylus 123 and the read head resolution as described in more detail hereinafter. Note that the resolution will be a function of the available state-of-the-art technology for miniaturizing the extent of the field 200; therefore, given such read-write head advancements to the state-of-the-art, it is contemplated that even a single molecule electro-optical memory cell can be implemented. Spacing between the stylus tip 223 and the recording layer surface 205 - sometimes referred to in the art as the "flying height" when the stylus tip 223 is not in contact with the surface to prevent wear, crash damage, and the like - will also be a factor affecting bit density. Thus, it can be seen that with advances to the state of the art of stylus 123, or to a combined read-write head, miniaturization, the accessible bit density of the recording layer is molecular in scale. That is, each molecule 109, FIGURE 1, having a

rotor 109r - - molecular connector - - stator 109s

construction, is an individual bistable switch capable of representing a digital "1" or digital "0" data bit depending on its currently set, bistable, state. In other words, for the current state of the art for read-write heads, the rotational state of the rotors of

a superset of molecules 109 at each data bit position along the recording medium 107 determines the data bit state at that position of the disk 103 surface 105. As an analogy, one can think of a superpixel in a visual color image where each visible superpixel may actually comprise an array of smaller pixels. Thus, a data bit is reversibly written electrically, by using a stylus 123 generated local electrical field 200 passing through the recording medium 107 between the stylus tip 223 and the disk 103 substrate ground potential. In one exemplary embodiment, the recording medium 107 has data bits represented by regions absorptive of incident light by a molecule or predetermined superset of molecules is in one of the bistable modes, representing a first data bit molecular configuration, and data bits represented by regions transmissive of incident light in the other of the bistable modes, representing a second data bit molecular configuration; e.g., absorptive molecule(s) can be a digital one or digital zero with the transmissive molecule(s) being complementary thereto.

[0018] With appropriately adapted read heads, other configurations for at least two-bit determinative data modes may be implemented. For a two optical state molecule, the alternative bit regions may be (1) reflective and transmissive, or (2) differential reflective or differential absorptive, or (3) differential

refractive indexed. Note that in addition to the visible light spectrum, implementations can be tailored for infrared and ultraviolet spectral radiation as well.

[0019] It is to be specifically recognized that using combinations for data modes is a recognized implementation; e.g., reflective/white = 1, absorptive/black = 0, and transmitted and separately received = a third datum state. Moreover, recognizing different reflected colors - - e.g., where the molecules switch between red and yellow may also be indicative of different data bit states. Also note that optical recording and recognition of a variety of colors may be used for multi-statible data.

[0020] **FIGURE 3** is a simplified block diagram of an exemplary system for employing the exemplary embodiments of the present invention. The system 300 schematically depicts read-write components of what is generally referred to commercially as a "disk drive."

[0021] The memory disk 101 having the recording medium 107 is mounted on a spindle 301 connected to a motor 303. Rotational motion, represented by arrow 303R, is selectively imparted to the disk 101 by the motor 303 under control a controller unit 305. The controller unit 305, such as a microprocessor or application specific integrated circuit (ASIC) based printed circuit board, provides known manner firmware or software based instructions

for both data handling and disk read-write-erase operations. "INPUT DATA" - e.g., from a host computer, not shown - is received by recording buffer/write head driver circuitry 307 which is used by the controller unit 305 to write erasably onto the memory disk 101.

[0022] Note that it is recognized that translating media over read-write heads is an alternative to relative rotational and radial juxtapositioning. This is also described in co-pending U.S. Pat. Appl. Ser. No. 10/264,811 by Vincent et al., assigned to the common assignee herein, for FIELD ADDRESSABLE REWRITABLE MEDIA.

[0023] Once a disk 101 recording medium 107 is written on as described hereinbefore, it has a recording layer with discrete regions representative of digital data bits in that data bit regions in this particular exemplary embodiment of the layer are either absorptive of incident light and either reflective of incident light - - where for example the disk substrate is metal, metal oxide, metal halide, metal sulfide, silicon nitride, or inorganic materials - - or transmissive of incident light, where for example the disk substrate is a transparent plastic. The exemplary embodiment shown in FIGURE 3 illustrates the latter.

[0024] A read head 311 is a light source directed at the disk 101 and movable along a radius of the disk, illustrated by horizontal

arrows 311L, 311R. The transmitted light for transmissive bit regions is captured by a photodetector 313. That is, in this exemplary embodiment in general, at a given spectral band used to read the data bits, data bit states are differentiated as photon absorbent where the colorant molecules are in an opaque state, and either photon transparent down to the reflective substrate 103 or photon transmissive where the colorant molecules are in a transparent state. The photodetector 313 signals are processed in a known manner by means of circuitry for reproduction amplification 315, analog-to-digital conversion 317, and buffering 319 back to the controller 305 for "DATA OUTPUT." It will be recognized by those skilled in the art that a combined read-write head can be implemented as a single unit subsystem.

[0025] In the aforesaid manner, the colorant is a plurality of stratum of a matrix structure forming a regular lattice of said molecules such that predetermined volumes of said colorant form predetermined targetable positions of said memory means wherein each of said positions is a memory location of the disk for writing and erasing using the localized electrical field and reading using a known manner optical emitter-detector.

[0026] While FIGURE 3 represents data bits using a mechanism for a two optical state molecule where the alternative bit regions are reflective and transmissive, it can now be recognized that

simple modifications can be implemented for bit regions that are differentially reflective such as by having a detector for recognizing gray scale differences. Similarly a detector may be employed which is sensitive to bit regions that are differentially absorptive. Additionally, by employing molecules where the states are differentially refractive indexed, and employing a detector that senses the specific light path changes of a read head incident beam, the same results can be achieved. It is specifically recognized that combinations of these three modes of recording data may also be employed.

[0027] The media surface recording medium 107 may be constructed to meet data bit standards currently in use for current and future CD and DVD data storage apparatus. In the current state of the art, for a low cost implementation, the recording medium 107 may be on a reflective, e.g., polished aluminum, disk substrate 103. Incident light passes through each transmissive data bit area and reflects back. This allows the use of low cost, commercially laser emitter-detector components common to CD and DVD formats.

[0028] It can now be recognized that given the adapted read-write head technology, in accordance with the present invention it is possible to increase data memory such that each data bit is stored in a single molecule. Such technology is sometimes

referred to in the art as “nanotechnology” in that one or a few molecules form a machine. In the present invention, that machine is a bichromal, bistable, electrically controlled switch. That is, with the present invention the data domain of each data bit can be on the order of merely several Angstroms or nanometers, which is orders of magnitude greater compared to state of the art CD and DVD technology where state-of-the-art bit size is limited to about 400 nanometers. Even using current state of the art write heads produced with known manner semiconductor fabrication techniques and read heads where minimum field of view is much greater than the molecular level, in computer modeling, simulations or experiments conducted by the inventors, switching time - - that is, data recording - - can be reduced to 10^{-9} seconds.

[0029] As described hereinabove, the present invention thus provides a method and apparatus for a rotating disk rewritable memory using an electro-optical molecular recording layer. In the manner of nanotechnology, each molecule is an individual switch having two distinct optical characteristic states. Localized electrical field injection is used to switch each molecule to one of two bistable states such that each is representative of a digital data bit.

[0030] The foregoing Detailed Description of exemplary and

preferred embodiments is presented for purposes of illustration and disclosure in accordance with the requirements of the law. It is not intended to be exhaustive nor to limit the invention to the precise form(s) described, but only to enable others skilled in the art to understand how the invention may be suited for a particular use or implementation. The possibility of modifications and variations will be apparent to practitioners skilled in the art. No limitation is intended by the description of exemplary embodiments which may have included tolerances, feature dimensions, specific operating conditions, engineering specifications, or the like, and which may vary between implementations or with changes to the state of the art, and no limitation should be implied therefrom. Applicant has made this disclosure with respect to the current state of the art, but also contemplates advancements during the term of the patent, and that adaptations in the future may take into consideration those advancements, in other word adaptations in accordance with the then current state of the art. It is intended that the scope of the invention be defined by the claims as written and equivalents as applicable. Reference to a claim element in the singular is not intended to mean "one and only one" unless explicitly so stated. Moreover, no element, component, nor method or process step in this disclosure is intended to be dedicated to the public

regardless of whether the element, component, or step is explicitly recited in the Claims. No claim element herein is to be construed under the provisions of 35 U.S.C. Sec. 112, sixth paragraph, unless the element is expressly recited using the phrase "means for. . ." and no method or process step herein is to be construed under those provisions unless the step, or steps, are expressly recited using the phrase "comprising the step(s) of. . .." What is claimed is: